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RADIAL DAMPING BY OCTUPOLE FOR ZGS BEAM

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Abstract

Landau damping by the octupolar tune spread is used to prevent the radial blowup of the beam during the acceleration cycle. The octupole field is produced by a set of pole face windings in the ring magnets. The strength of the octupole field, which is controlled by the Zero Gradient Synchrotron (ZGS) programmer, is set to give a tune profile of $\nu_x = 0.83 + 0.008 \times a^2$, where a is the radial coordinate of the aperture in unit of cm. The radial damper feedback system, which has been operating for some years, has been replaced by this octupole, and the radial stability is remarkably improved by the new system.

Introduction

It has been known that beam blowups occur during the early acceleration cycle of the ZGS due to various effects such as the resistive wall.¹ In order to prevent these blowups, beam feedback damper systems have been used for both the radial and vertical betatron motions.^{2,3} However, the performance of the radial damper system has been somewhat less than adequate. It needed constant adjustment by the operator, and although it functioned well enough to prevent beam loss, the beam size growth near 3 ~ 5 kG of the acceleration cycle persisted.

During the ZGS vacuum chamber changeover, a set of pole face windings was installed to make corrections for the eddy current sextupole and remnant field components of the ring magnets. Since these corrections have to be made during the early acceleration cycle, the amplitude of the corrections is necessarily small. A set of controls originally intended for the remnant field correction, was used to produce an octupolar field by adding and subtracting currents to the eddy current correction windings. Because of the original purpose of the correction, the effective octupole field strength that can be generated by this system is limited to lower fields. However, since the blowup also occurs at a lower field, it was considered to be adequate to damp the blowup. Indeed, remarkably improved stability was observed. Details of the pole face winding system are described elsewhere.⁴

Experimental Observation

Figure 1 shows the radial beam size, number of protons/pulse, Q_A , and a marker indicating an approximate field in which the blowup occurs. Q_A during this experiment was about 2.2×10^{12} protons/pulse and the observed radial blowup was as big as eight inches. When the blowup is this large, a beam loss usually occurs at this point.

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Fig. 1. (A) Radial size 4"/division
(B) Vertical size 2"/division
(C) Marker at 5 kG
(D) Q_A
with octupole off.

At first, we energized the octupole to give a radial tune spread of $\Delta\nu_x/a^2 = 0.004/\text{cm}^2$ at the accelerating field of 1 kG. The ZGS programmer was commanded to keep this tune profile up to 8 kG. Above 8 kG, due to the inability of subtracting more currents from the eddy current correction windings, the B'' was held constant to the peak field of 19.8 kG. At this point, improved stability was observed.

The optimum tune spread obtained by tuning the octupole strength was $\Delta\nu_x/a^2 = 0.008/\text{cm}^2$ at a Q_A of about 2.3×10^{12} protons/pulse. Figure 2 shows Q_A , radial beam size and the marker with the octupole energized. It is evident that the radial blowup is eliminated by the octupole. It should be noted that the ZGS has a tune relation of $\nu_x^2 + \nu_y^2 = 1.345$, and $\Delta\nu_x/a^2 = 0.008/\text{cm}^2$ produces $\Delta\nu_y/a^2 = -0.008$ at the normal ZGS tune of $\nu_x = 0.83$.

There is an additional complication in the tune profile introduced by the octupole field in the ZGS. The equilibrium orbit in the ZGS during the injection is circular. As the field increases, the orbit deforms due to the diminishing effect of the dc magnets in the four short straight sections. This orbit change causes the beam to "see" more of the inside aperture than the outside. Tune measurements as well as calculations at various accelerating fields show that the orbit deformation causes a shifting of the origin

Fig. 2. (A) Radial size 4"/division
(B) Vertical size 2"/division
(C) Marker at 5 kG
(D) Q_A
with octupole on.

of the parabolic tune profiles. To compensate for this shifting, a quadrupole correction function was introduced in the pole face winding system.

If the strength of the octupole is raised to a higher value, it is necessary to raise the gain of the vertical damper system. The reason is that the over damping in one direction causes a blowup in the other direction. With higher ZGS intensities, which have been achieved recently with a new injection scheme, the balancing between the octupole strength and the vertical damper gain is essential to eliminate the instabilities due to the high intensity.

Conclusion

Landau damping due to tune spread generated by an octupolar field was successfully used to prevent the radial blowup of the beam during the accelerating cycle of the ZGS. Together with the vertical damper feedback system and a new injection method, the ZGS has accelerated a weekly average intensity of above 5×10^{12} protons/pulse.

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